§57. Real-time Equilibrium Calculation and Control on QUEST

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A real-time equilibrium calculation code has been developed on QUEST for the control of plasma position and its shape. In the last year, a simple method to calculate positions of the last closed flux surface (LCFS) in real-time was installed into the control system of QUEST. This method assumes that the broadened plasma current as one filament current located on the gravity point of the plasma current profile. This point is calculated from the flux loop signals with a pre-calculated data matrix. This method can calculate LCFSs within 0.5 msec with the grid resolution of 50×80 and the area of $0.0 < R\ [m] < 1.5$, $-1.2 < z\ [m] < 1.2$.

In this year, the plasma current profile is treated as the bundle of filament currents located on the grid points, and the force balance equation of the Grad-Shafranov (GS) equation is considered with using previously developed routines in the last year. The number of unidentified constants to represent the pressure function and the square of the poloidal current function are two, respectively. Thus, the four parameters are determined by solving the GS equation with the least mean square method between the calculated and measured flux signals and the calculated and assumed plasma current profiles. The time to calculate one period is evaluated as 12.2 msec with the same grid resolution using a single core of the quad core CPU of the plasma control system. Here, one period means that a new plasma current profile is determined from an old one by solving GS equation one time, and does not includes its iteration of calculations. As a result, the part to represent the plasma current profile and flux signals with the unidentified constants takes 81% of one period time. This part can not be expected to become faster with a further modification of the coding, and this period is much longer than its power supply response time and the time constants of eddy currents effect, and is insufficient to control the plasma position and its shape. Therefore, the grid resolution is set coarsely to 30×48, referring to the rtEFIT case (33×33)[1]. With this case, one period time becomes shorter to 1.65msec. This period time is roughly proportional to the square of all the grid points ($\sim(30\times48)^2/(50\times80)^2$), and is comparable to the time constants of power supplies and the eddy currents effect. Figure 1 shows an example of the calculation results with the typical divertor configuration discharge.

The inside edge position control is tested for the sustainment of the divertor configuration, calculating the plasma position and shape in real-time with the one filament method developed in the last year, because the real-time equilibrium calculation code has not been installed yet into the control system. In this control, the inside edge position of plasma is calculated in real-time, and the center solenoid coil called the PF4 coil is used to control its position with using a proportional-integral-derivative (PID) control loop. Figure 2 shows the result. The control starts from 2.0 sec, and the target inside edge position is increased up to 0.30 m from 2.0 sec to 3.5 sec and decreased to 0.25 m from 3.5 sec to 3.8 sec (Fig. 2. (b)). According to this increase and decrease of the target value, the PF4 coil current is adjusted by the PID control loop (Fig. 2. (c)) via the target and the calculated inside edge position. As a result, the calculated inside edge position is well controlled to be same to the target position (Fig. 2. (b)).

In the future study, the real-time equilibrium calculation code will be installed into the control system, and the other edge positions such as the top, bottom, and outside edge positions calculated with this code will be controlled with other poloidal field coils in order to control the plasma shape.

1) Gates, D.A. et al.: Nucl. Fusion **46** (2006) 17-23

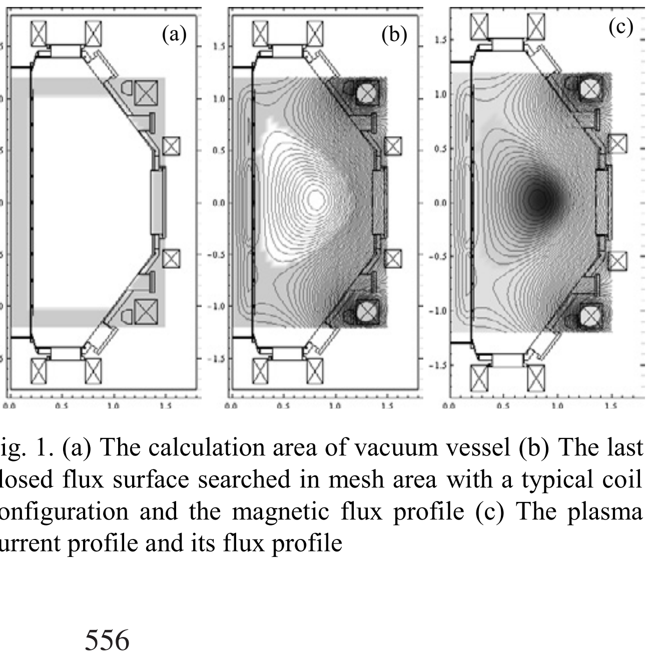

Fig. 1. (a) The calculation area of vacuum vessel (b) The last closed flux surface searched in mesh area with a typical coil configuration and the magnetic flux profile (c) The plasma current profile and its flux profile

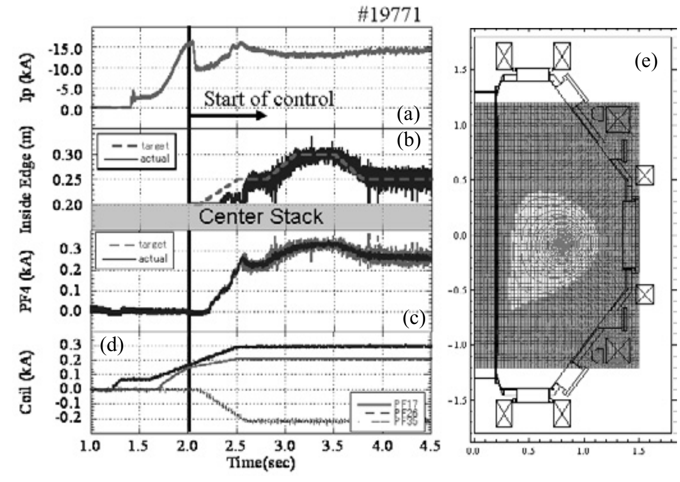

Fig. 2. The inside plasma edge position control for divertor configuration (a) the plasma current , (b) the inside plasma edge positions of the calculated (solid) and target (dashed) ones, (c) the coil currents for the control of the inside edge position, (d) other coil currents, and (e) the plasma shape at 3.5 sec assuming the plasma current profile as one filament current.